EXPLORING RISK MANAGEMENT IN THE WARNING DECISION-MAKING PROCESS

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February 2003

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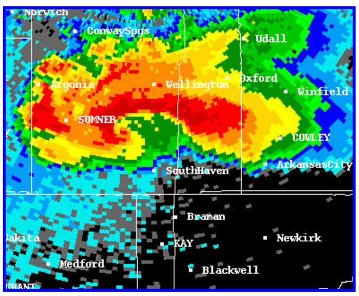
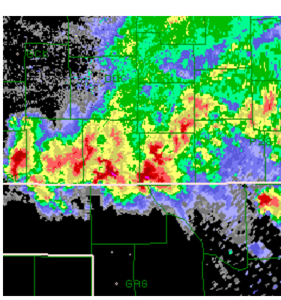
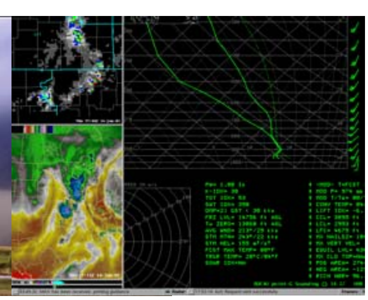


Risk Management

In this presentation, we'll focus on 3 primary data sets used in convective warning decision-making.

RADAR | **SPOTTERS** | **ENVIRONMENT**





Outline

I Introduction and Exercise

II What is Risk Management?

III Why is Risk Management important in the warning decision-making process?

A) Uncertainty with radar
B) Uncertainty with spotter observations
C) Uncertainty with environment data
D) What customers expect from us
E) How can we use probabilistic ideas to make better deterministic decisions?

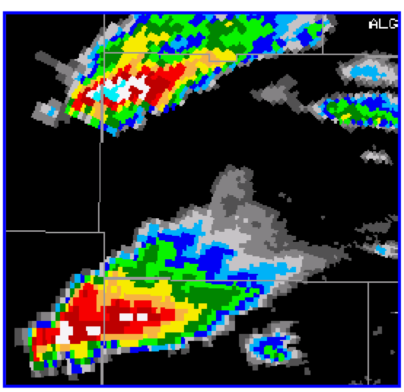
IV **"Weigh the Evidence"** approach

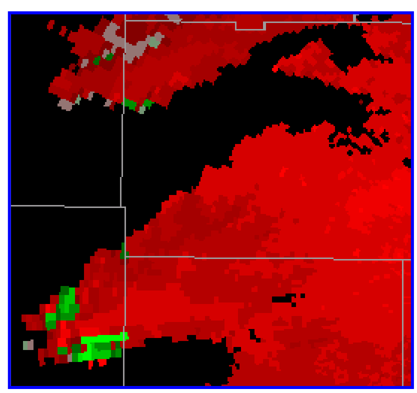
V Case examples

VI Conclusion

Let's start with an exercise

Consider the Following…



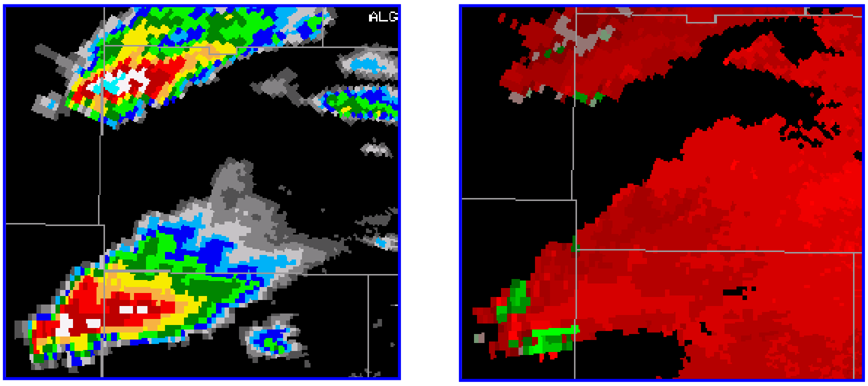


Take a look at the 2 storms to the left. Using only these 0.5 degree reflectivity and SRM images (from a WSR-88D about 30 nm to the east):

--Would you issue a SVR or TOR for the **northern** storm?

--Would you issue a SVR or TOR for the **southern** storm?

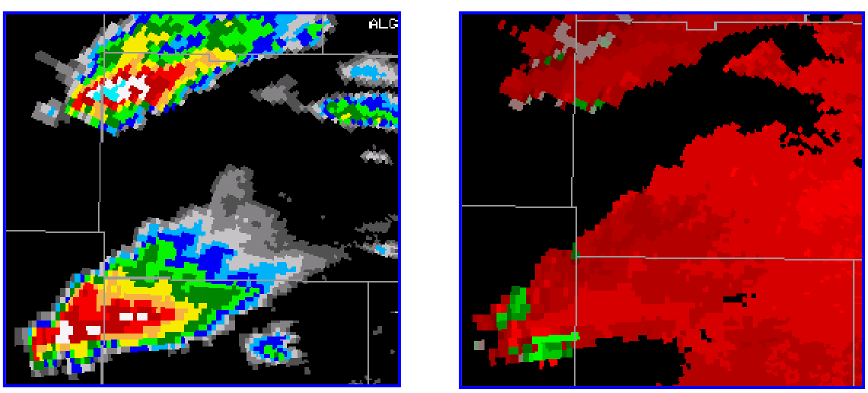
Consider the Following…



Okay, radar shows that the **northern** storm has a strong mesocyclone (max rotational velocity around 45 kts), about 10,000 feet deep, above the 0.5 degree elevation slice.

--Would you go with a SVR or TOR for the **northern** storm?

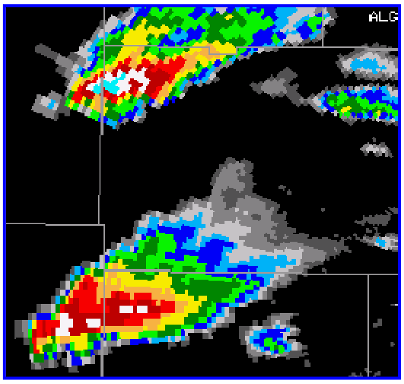
Consider the Following…

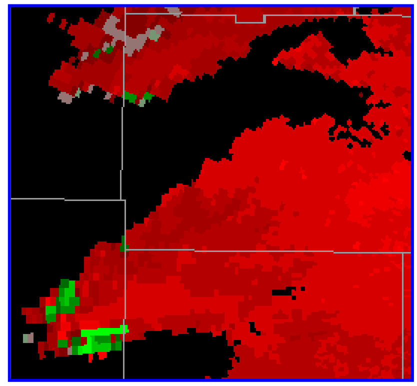


Okay, a spotter just reported a rotating wall cloud with the **southern** storm.

--Would you go with a SVR or TOR for the **southern** storm?

Consider the Following…

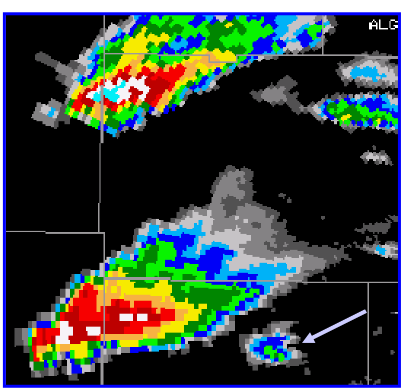


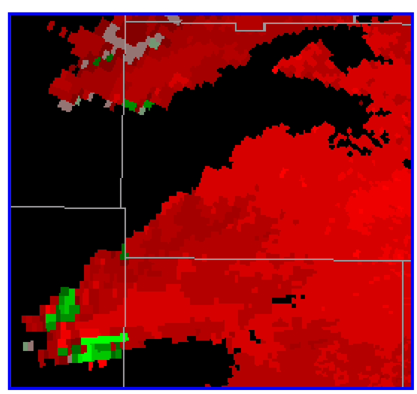


RUC and LAPS soundings show a strong frontal inversion at and below 875mb (surface front located 50 miles to south of southern storm). Above inversion, there is moderate instability and strong speed shear. Environment data suggest storms are likely elevated.

--Would you issue a SVR or TOR for the **northern** storm?
--Would you issue a SVR or TOR for the **southern** storm?

Consider the Following…

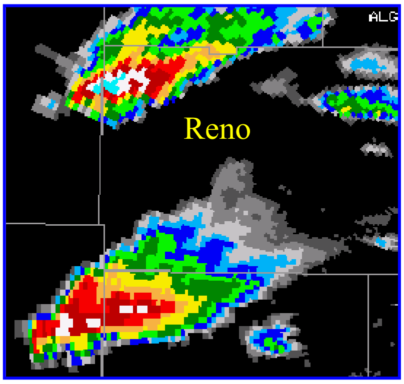


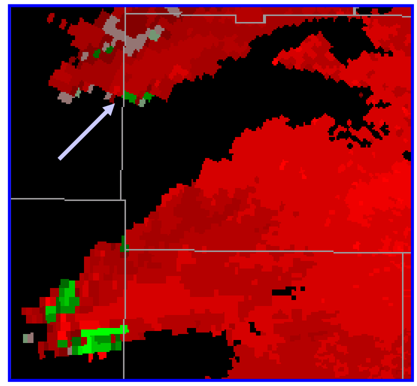


Wait, those environment soundings were a few hours old. Latest data shows surface front has reformed just south of **southern** storm (arrow points to new cell just ESE of southern storm), with a much weaker, shallow inversion shown on RUC and LAPS soundings.

--Would you issue a SVR or TOR for the **northern** storm?
--Would you issue a SVR or TOR for the **southern** storm?

Consider the Following…

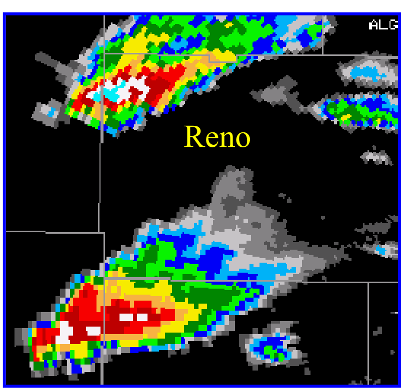


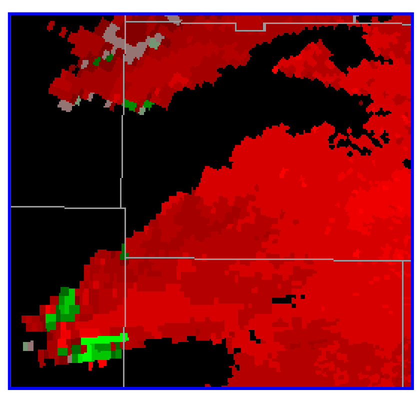


Now let's say the **northern** storm was possibly tornadic over $\frac{1}{2}$ hour ago, with a nice signature on velocity data on prior scans. The signature has weakened considerably on all elevation slices, as shown to the left, as the storm moves into NW Reno County. Similar rotation is seen aloft to what is shown (by arrow) to the left, 15-20 kts rotational velocity.

--Would you go with a SVR or TOR for the **northern** storm?

Consider the Following…

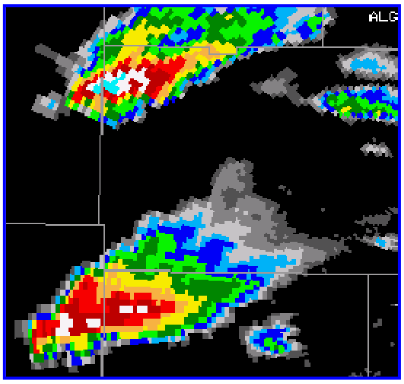


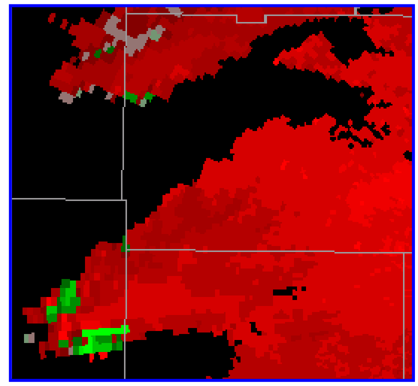


Law enforcement is getting a number of calls about funnel cloud sightings with the **northern** storm moving over northwestern Reno County.

--Would you go with a SVR or TOR for the **northern** storm?

Consider the Following…

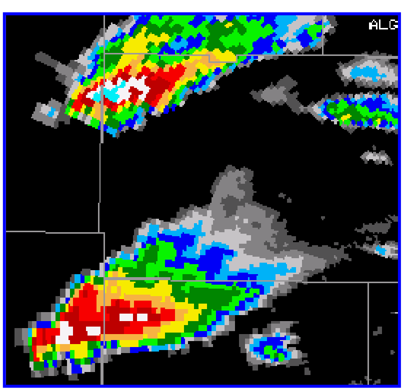


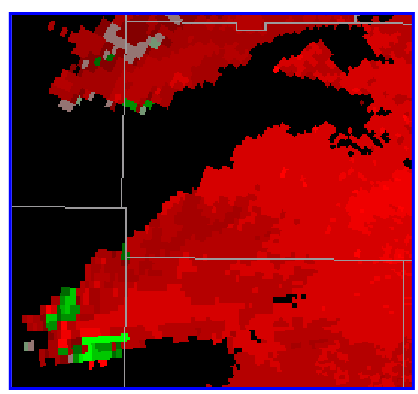


Wait! There's a trained spotter just south of the **northern** storm, looking north. The spotter reports a lot of scary-looking scud clouds, but no funnel clouds, barely even a wall cloud. Spotter cannot find any distinct cloud lowering or rotation.

--Would you go with a SVR or TOR for the **northern** storm?

What Happened?





Northern Storm **was not** tornadic. It was a large hail producer.

Southern Storm **was** tornadic, and was a large hail producer.

This case occurred in mid-April 2001 in southern KS.

How did your decisions change as new information was presented?

What is Risk, and Risk Management?

"**RISK** is defined as the chance of something happening that will have an impact on objectives. It is measured in terms of consequence and likelihood.

RISK MANAGEMENT is defined as the systematic application of management policies, practices, and procedures to the task of identifying, analyzing, assessing, treating and monitoring risk. "

Do you consider risk when it comes to convective warning decision-making?

(from a Univ. of New South Wales, Australia website)

Risk versus Uncertainty

UNCERTAINTY only relates to the likelihood of the occurrence of the event.

RISK is the probability of an undesirable event occurring **and** the significance of the consequence of the occurrence. So, to understand when a given decision is "risky", one must have an understanding of potential impacts resulting from occurrence/ nonoccurrence of event. In essence, decisions are riskier over population centers than out in no-where-land, because the consequences of wrong decisions are greater.

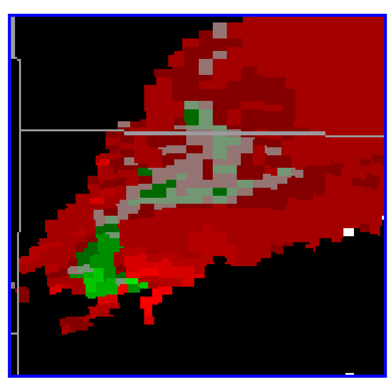
(from an American Graduate University website)

Why Is Risk Management Important in Convective Warning Decision-making?

- A level of uncertainty exists with the data used for warning decision-making (radar, environment, spotter).
  - Are the data accurate?
  - Is our interpretation of the data accurate?
- Considerable uncertainty exists with our knowledge of environment processes (e.g. tornadogenesis).
- The potential consequences vary (e.g. for storms threatening population centers vs. those in rural country).

Factors that increase the risk of an incorrect warning decision?

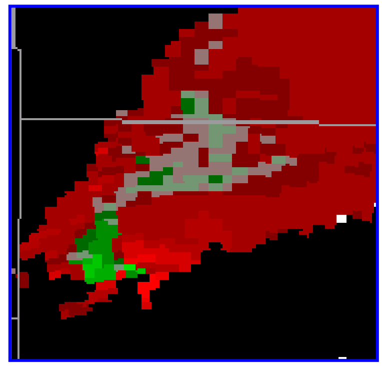
Let's say the velocity signature to the right is for a storm 70 miles to the west of a WSR-88D. What factors could cause one to make the wrong warning decision for this storm?



Factors that increase the risk of an incorrect warning decision?

Let's say the velocity signature to the right is for a storm 70 miles to the west of a WSR-88D. What factors could cause one to make the wrong warning decision for this storm?

1. Inaccurate radar data.
2. Inaccurate or incomplete knowledge of the near-storm environment.
3. Inaccurate or unavailable spotter reports.
4. Inaccurate conceptual models or other knowledge (e.g. tornadogenesis in a low shear environment, knowledge of populated locations).
5. Personal issues (e.g. distracting home issues, too many storms to deal with, fatigue, etc).



Uncertainty with Data Available

Exercise: List potential sources of error or misinterpretation associated with the following:

1) WSR-88D Output

2) Near-Storm Environment Data Sets

3) Spotter Reports

Uncertainty with Data Available

Exercise: List potential sources of error or misinterpretation associated with the following: (Not a complete listing)

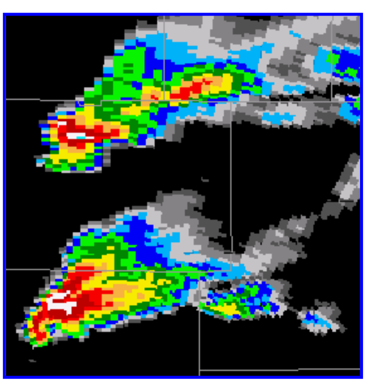
1) WSR-88D Output
   - a. Beam width/height vs range
   - b. Viewing angle (velocity)
   - c. Range folding
   - d. Lower res. data vs 8-bit,
   - e. Data overload in big events
   - f. VIL when max refl>60 dBZ
   - g. Improper de-aliasing
   - h. SRM vs base velocity,

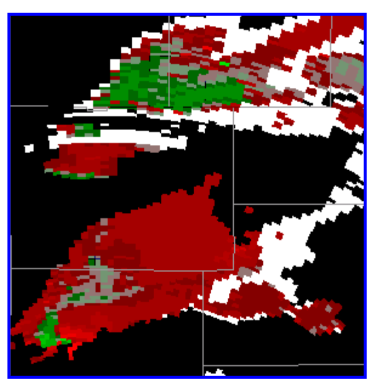
2) Near-Storm Environment Data Sets
   - a. Inaccurate observations
   - b. Large distance between obs
   - c. Conflicting data
   - d. Model data w/out observational support

3) Spotter Reports
   - a. Lack of spotters
   - b. Conflicting reports
   - c. Which storm is report for?
   - d. Inaccurate report

Uncertainty exists with radar

- Are radar data showing what's really happening?
- Are we correctly interpreting what the radar shows?

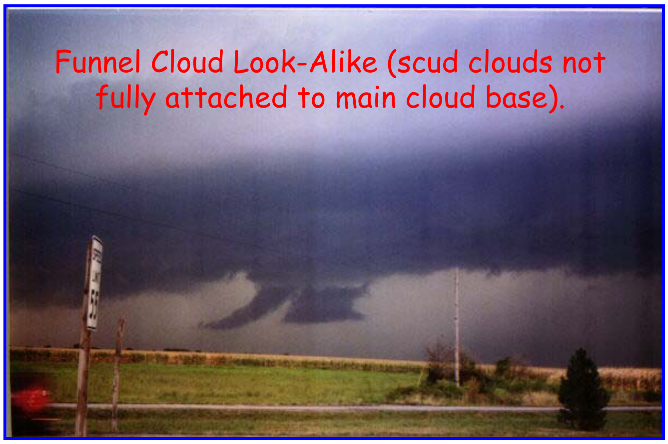




Are these storms tornadic?
Do you think southern storm has a higher or lower probability of tornadoes?
(Radar is located to south of storms.)

Uncertainty exists with spotter reports

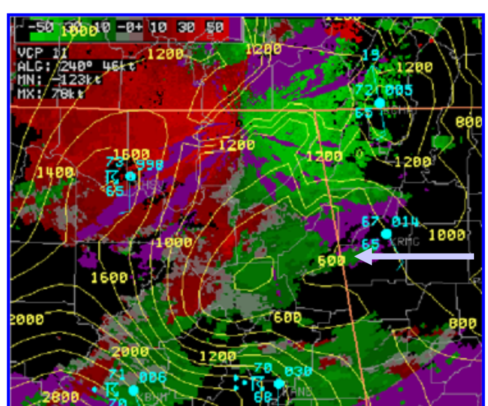
- Are spotters really seeing what they're reporting?
- Are spotters in a position to see a feature that may exist?
- Any uncertainty as to which storm a spotter is observing?



Uncertainty exists with environmental data sets

- Does the environment exist/change in time/space exactly as our data sets suggest?
- Are we correctly interpreting environmental change in time/space as our data sets suggest?

(Note the CAPE minimum over NE Alabama on LAPS plot to the right, where arrow is pointing. There are no surface observations across NE Alabama to help confirm the accuracy of this feature.)



Risk levels vary with each event, each storm, each decision

Radar Data

Risk increases with: increasing range, decreasing feature size.

Risk decreases with: decreasing range, increasing feature size.

Environment Data Sets

Risk increases with: increasing dependency on model data, decreasing observation coverage.

Risk decreases with: increasing dependency on multiple observations, increasing observation coverage.

Spotter Reports

Risk increases with: decreased number of spotters, decreased level of training, unfavorable spotter location.

Risk decreases with: increasing number of spotters (to corroborate each other), favorable spotter location.

What customers expect from us

- Timely, deterministic warnings of life-threatening events
- Sufficient information about the threat, provided as efficiently as possible
  - Yet data availability/accuracy issues, and our incomplete knowledge of tornadogenesis essentially lead to probabilistic decisions (i.e. we issue a warning when an event appears likely to occur)
  - The detail of information we can provide is based on our probabilistic decisions

So, what do you do…

What do you do when the data disagree?

- •Radar shows no organized rotation, but a spotter reports a funnel cloud and the storm is approaching a major town or city?

- •Radar shows a strong mesocyclone aloft and a spotter reports a rotating wall cloud, but the storm is in an area with a strong low-level inversion and weak shear?

- •Radar shows a supercell with moderate rotation in a favorable environment for tornadoes, but spotters underneath the storm report no funnels, and barely even a wall cloud, and the storm is over a large rural area where few live?

- •Radar shows a massive supercell with a VIL of 90, but velocity data is masked in range-folding, and given that it's nighttime, there are no spotters available?

How can we use probabilistic ideas to make better deterministic warnings?

•In the past, warning decisions were made based primarily on radar data, often without fully considering the accuracy of the data or the storm's environment

•Today, more tools are becoming available, including spotters and environmental data sets

•To answer the question above, we need to evolve from a "Radar-Based Decision" approach to a "Weigh The Evidence" approach

Weigh The Evidence

Why Not Warn Based Solely on Radar?

Past tornado warning verification statistics have shown that decisions based only on radar data can be problematic…

--- Radar signatures of tornado threat yield high false alarm rates

--- Despite many warnings issued due to radar, nearly a third of all tornadoes occurred without a warning with any lead time

--- Some tornadoes occur without a substantial radar signature

AVERAGE NWS TORNADO WARNING VERIFICATION SCORES THROUGH THE 1990s: POD: 0.60-0.65 FAR: 0.75-0.80

Verification Scores are gradually improving…

2000/2001 verification scores have shown some improvement in POD and FAR scores, likely due to:

- Better training/knowledge of storm structure/trends
  - Greater utilization of near-storm environmental info
  - Greater storm spotter support
  - Increased verification efforts

BUT, significant tornado missed events continue to occur (e.g. Newton MS, LaPlata MD, Hoisington KS)

"Weigh The Evidence" Approach

Image from WDTB

The "Evidence" includes:

-- Knowledge of data available

-- Knowledge of data not available

-- Knowledge of data accuracy/reliability

--Other factors

"Weigh The Evidence" Approach

--- Let's focus on the 3 data sets used in warning decision-making:

- WSR-88D radar
- Environmental data
- Spotter reports

--- Each data set available provides valuable clues regarding what will soon occur

--- Each one also provides a level of error, which varies from case to case

--- The warning forecaster must weigh what the data indicate with the potential data shortcomings

Here is where "risk management" comes into play. We incorporate our knowledge of risk (potential for error and resultant consequences) into the decision

Example scenarios when this is important

- Different data sets offer conflicting information:

  --- 88D shows little rotation, spotter reports funnel aloft

  --- 88D shows TVS signature for storm in an unfavorable environment for tornadoes

- Accurate data sets are replaced with less accurate ones:

  --- 88D 25nm away from a storm is down, so must use backup 88D located 100nm away from the same storm

  --- No surface observations in vicinity of storm, so one looks at model analysis fields to study near-storm environment

  --- No trained spotters available, yet reports of funnel clouds are received from public

"Weigh The Evidence" Approach

In this approach, the warning forecaster must incorporate all available data and knowledge of data accuracy into the decision:

Radar data, keeping in mind the limitations and error sources of the data. Example questions:

What impact will beam height/width have on data? Is range folding or improper de-aliasing occurring? Is VIL being affected by storm motion or tilt? Are there reflectivity values > 56 dBZ not used in VIL calculation?

Greater weight: closer storms, larger signatures, VCP 11

Lesser weight: distant storms, larger signatures, VCP 21

"Weigh The Evidence" Approach

Near-storm environmental information (perhaps from a "meso-analyst"), making sure data are QC'd.

Are environmental data supported by actual observations? Are observations of questionable accuracy corroborated by other observations of greater reliability?

Greater weight: model data supported by observations, reliable observations, corroborating observations

Lesser weight: model data not supported by observations, observations of questionable accuracy, distant observations

"Weigh The Evidence" Approach

Spotter reports, keeping in mind the exact source of the reports (trained or untrained?) and location of spotters relative to storm of interest.

For several storms close together, which storm is the spotter observing? Does spotter actually see rotation, or just a cloud shape? Does a spotter, who is reporting no tornado, potentially have his/her view blocked by rain/hail shafts?

Greater weight: reliable report source, corroborating reports, favorable spotter location

Lesser weight: unreliable source, one report, bad spotter location

“Weigh The Evidence” Approach

At times, no spotters will be available, or perhaps no environmental data, or even no low-level radar data.

The warning forecaster needs to “weigh the evidence” available, and consider increased risk present from:

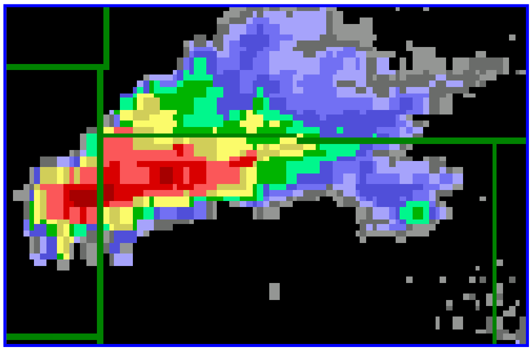
- having one or more data sets not be available
- utilizing data of questionable accuracy
- other factors, such as population centers threatened, storm history, etc

Varies from event to event, and from storm to storm.

“Weigh The Evidence” Approach

The next several slides show some examples of past warning decision scenarios. Weigh the evidence provided to you, and determine if a tornado warning should be issued or not.

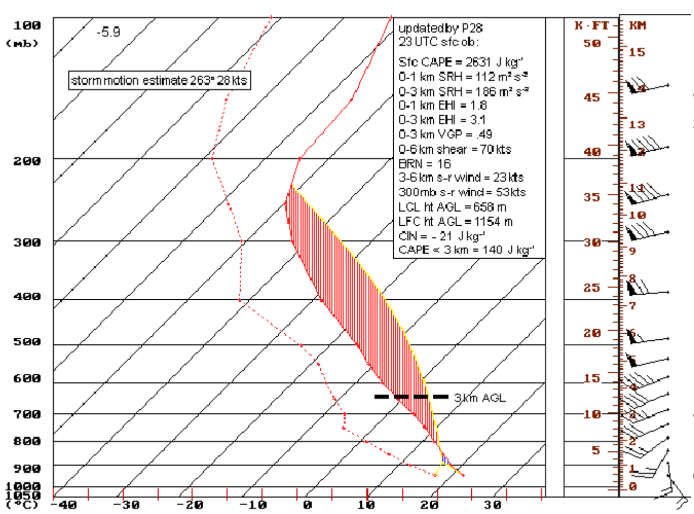
Example 1: Tornado Warning: YES or NO?



Radar 30nm away shows supercell. Velocity data is range folded, but prior scans showed weak rotation.

A spotter reports a dark, turbulent sky, but cannot see any funnel or wall cloud whatsoever.

Example 1: Tornado Warning: YES or NO?

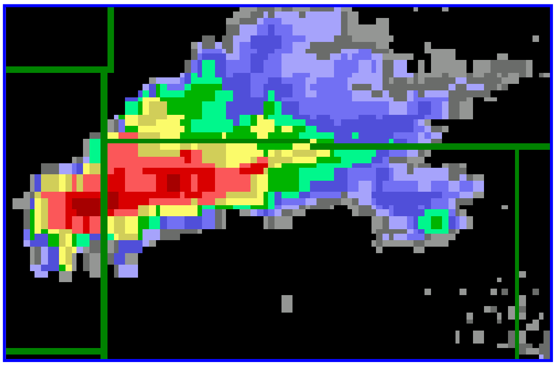


RUC "near-storm" analysis sounding shows:

- -CAPE > 2600
- -0-3km SRH>180
- -LCL at ~650m
- -VGP almost .50

Data appears reasonably accurate based on nearby observed data.

Example 1: Tornado Warning: YES or NO?



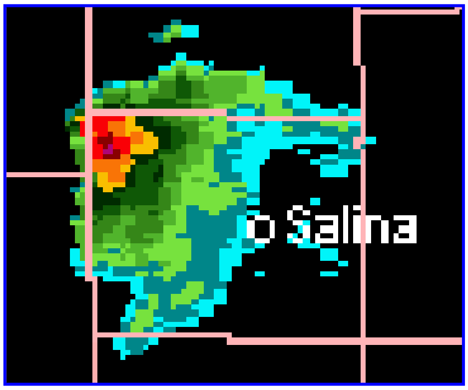
Range folding is removed to reveal strong (40-50kts) rotational signature on the lowest 2 slices. Storm is moving toward a few towns.

A spotter to the north of the storm looking south, reports a dark, turbulent sky to the south, but cannot see any funnel or wall cloud whatsoever.

Example 1…Conclusion

Hopefully your answer is **YES** regarding a tornado warning now! Inaccurate radar/spotter information (or lack of knowledge of spotter location relative to pertinent storm attributes) could have led to a missed event. The result was a strong tornado in Pratt County KS in mid-April 2001.

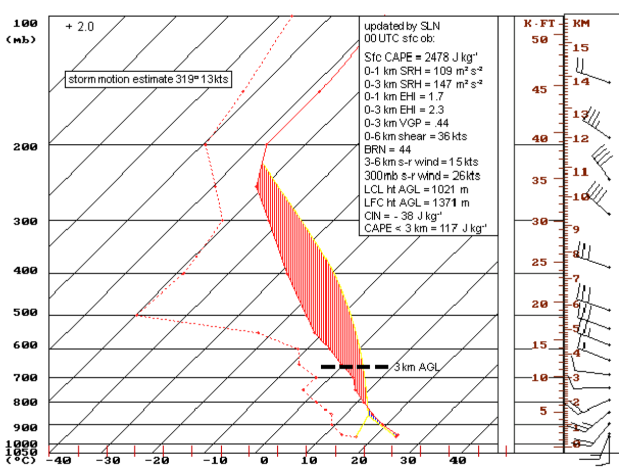
Example 2: Tornado Warning: YES or NO?



Radar shows strong storm over 90nm away, possibly a supercell, but only weak rotation on first elevation slice about 10kft above the ground.

No spotter reports are available.

Example 2: Tornado Warning: YES or NO?



Environment shows very little to oppose tornadogenesis:

- -CAPE nearly 2500
- -0-3km SRH ~150
- -LCL about 1000m
- -VGP around 0.44
- -No low-level inversion

Example 2: Conclusion

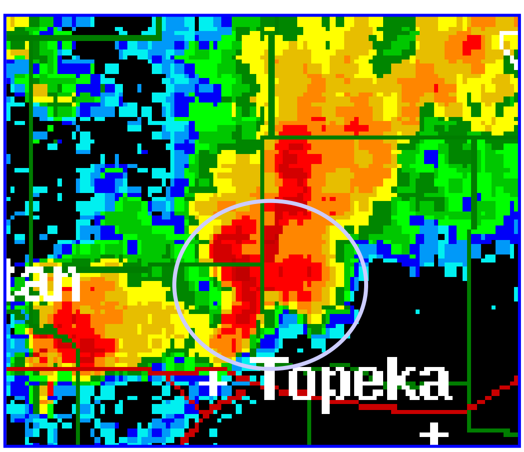
•Difficult case…no tornado occurred

•Environment fairly supportive of tornadic storms, yet radar data does not appear favorable. Given the height/range beam issue, and size of storm, one cannot give large weight to radar data. Use a closer radar, if available.

•Although no tornado occurred, there may be enough in the environment data to justify a warning.

•The best option, when available, is to get help from available spotters or law enforcement officials, which may help you make a better decision, even if the decision ends up being to wait for a later radar scan.

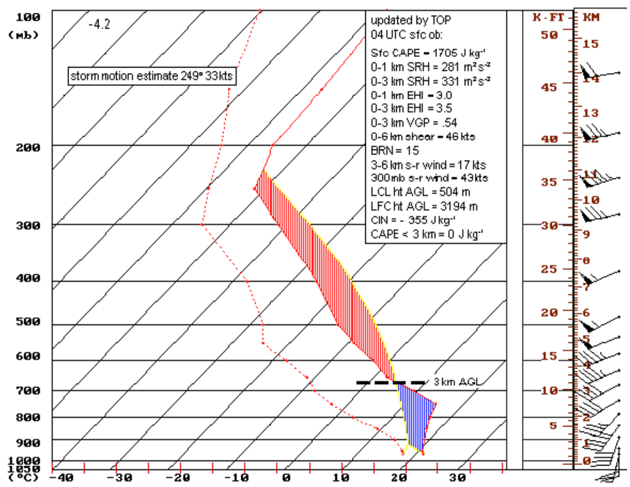
Example 3: Tornado Warning: YES or NO?



Storm just north of Topeka KS within 20nm of 88D, with some apparent supercell characteristics, but rotation is shallow, and only reaches "minimal mesocyclone". Storm is over a populated area.

It is late in the evening, and no spotter reports are available.

Example 3: Tornado Warning: YES or NO?



Near-storm environment sounding (from Eta analysis, and supported by nearby observations) supports elevated supercells…very large CIN (in blue) is a negative factor for tornadoes.

Do you go with a Tornado Warning now or wait for further clues?

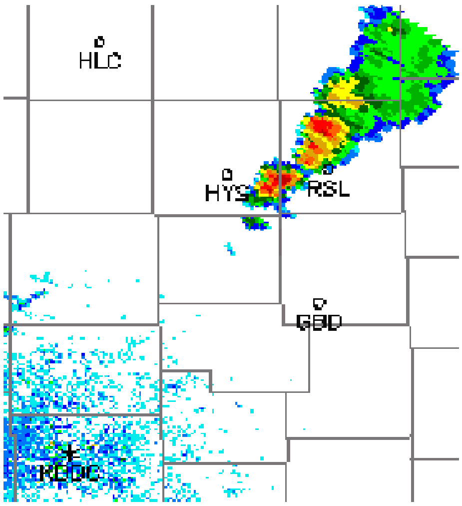
Exercise 3: Conclusion

•This is not a setup where one might want to jump on a tornado warning. Reliable spotter support might make a difference between an accurate warning and a false alarm. What data are available suggest elevated storms with little potential for a tornado. Thus, this may be a case where the best answer is **NO** (regarding an immediate tornado warning), but continue to monitor for new clues as to what may soon happen.

•**BE CAREFUL:** While substantial low-level CIN exists, the wet-bulb temp. curve is likely close to pseudo-moist adiabatic. If storm were able to tap the boundary layer (as suggested by increasing low-level rotation), perhaps through saturation of lower layers, tornado potential would increase markedly.

•No tornado occurred in this case.

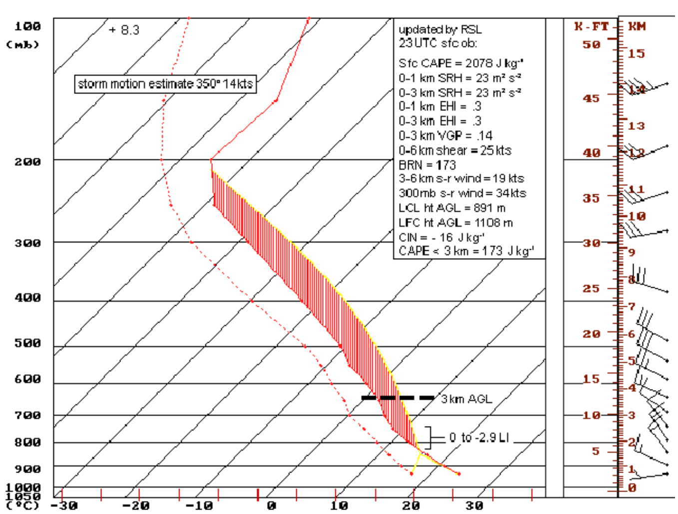
Example 4: Tornado Warning: YES or NO?



KDDC radar showed small storms moving SE. Very little rotation at best was detected. Storms were between 90 and 100 nm from KDDC radar.

A trained spotter reports a funnel cloud north of Russell, Kansas (RSL)

Example 4: Tornado Warning: YES or NO?



Environment sounding for Russell KS shows decent instability, but insufficient shear for tornadic supercells:

-CAPE=2078
-0-3km SRH=23
-0-6km shear=25kts
-0-3km VGP=0.14

Storms are moving SE on a well-defined boundary.

Exercise 4: Conclusion

•Several F0 tornadoes occurred!

•Environment/radar not suggestive of typical supercell tornado potential.

•**BUT**, conditions favored another means of tornado potential: vertical stretching of vertically-oriented vorticity along a persistent boundary! At over 90nm from radar, radar data should get very low weight (use a closer radar if possible to detect low-level features). The environmental clues correctly indicated little supercell-tornado potential, but also suggested decent potential for non-supercell tornado (large low-level CAPE, boundary). The spotter report should be enough for a tornado warning in this case.

Not all data are the same
(at least in terms of quality/accuracy)

Radar:
- More weight: storm close to RDA, large signature
- Less weight: distant storm, small signature

Spotters:
- More weight: trained spotters, good viewing location
- Less weight: untrained public, bad viewing location

Environment Data:
- More weight: reliable observational data close to storm
- Less weight: unreliable data, model data, distant observational data

Conclusion

Risk Management is important when it comes to making more accurate and timely warning decisions, while also reducing the potential for missed significant events. This requires weighing all available evidence, which requires:

--- knowing what data are available and what are not,

--- recognizing potential error of available data,

--- understanding potential consequences of incorrect decision.

We may continue to improve warning decision-making and produce better verification statistics, but without effective "**risk management**", we will continue to see significant misses.

Should we just issue a tornado warning for every rotating storm, or every funnel cloud report?

-- That's not "managing risk", that's "minimizing risk".

--Sure, such action would greatly reduce the potential for significant misses, but at what cost? Do we even need meteorologists if this is the best approach?

--This would be like having banks refuse to give loans to minimize the risk of defaults…how is this beneficial to the people.

Conclusion

What steps can be taken to "manage risk" when making convective warning decisions?

EXAMPLES:

1) Take steps to ensure spotter/law enforcement availability in population centers to help ensure correct decisions.

2) Base tornado warnings on threat to life/property
   --- Strong rotational signatures should be covered in the absence of spotter/environment data that suggest otherwise.
   --- Consider the concept of "legitimate false alarms" (since we are not to the point of differentiating between funnel cloud events and tornado events.

3) Incorporate "meso-analyst" position to QC available data and keep warning team updated on environment change in time/space.

4) Sectorize warning responsibility during larger events.

The Best Risk Management Approach to Convective Warning Decision-Making

-- Warn based on **threat to life/property**, not based on verification probability.

-- **Threats to life/property:** TVS/strong mesocyclone signature, funnel cloud, rotating wall cloud.

-- These features **"verify" the threat** covered by the warning.

-- Warnings verifying a threat, but not an actual event, should be considered "legitimate false alarms".

--For such instances, we should be thankful no one gets killed, rather than upset the warning didn't verify with an event.

THE END